Estimating the external costs of nitrogen fertilizer in Minnesota

2015 FARM BILL ASSISTANCE PARTNERSHIP WINTER MEETING

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natural capital PROJECT

INSTITUTE ON THE ENVIRONMENT
UNIVERSITY OF MINNESOTA
Driven to Discover℠

The estimated social cost of nitrogen fertilizer application is $893 million annually

Road Map

Why estimate the external costs of nitrogen fertilizer?

Land use and nitrogen fertilizer application in Minnesota

Spatially-explicit damage cost estimates

Where do we go from here?

Road Map

Why estimate the external costs of nitrogen fertilizer?

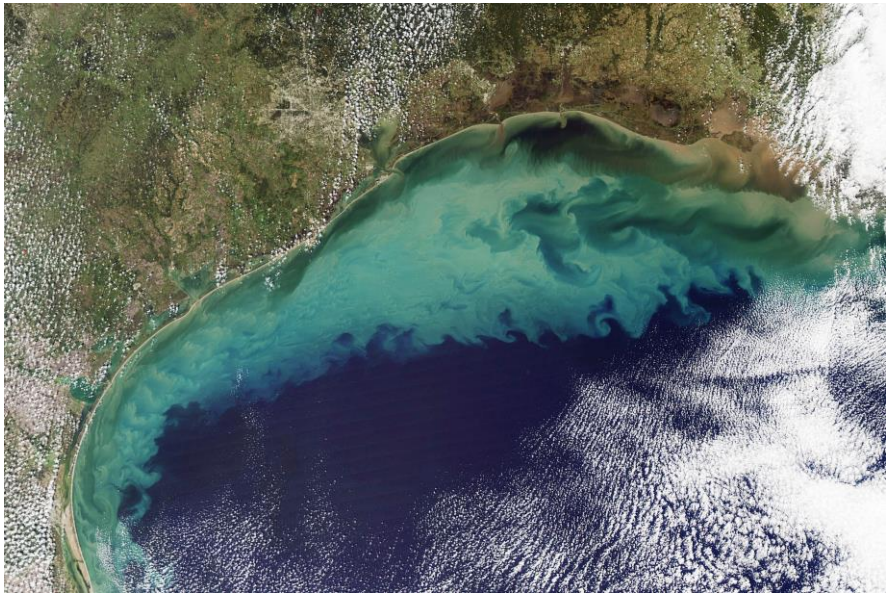
Land use and nitrogen fertilizer application in Minnesota

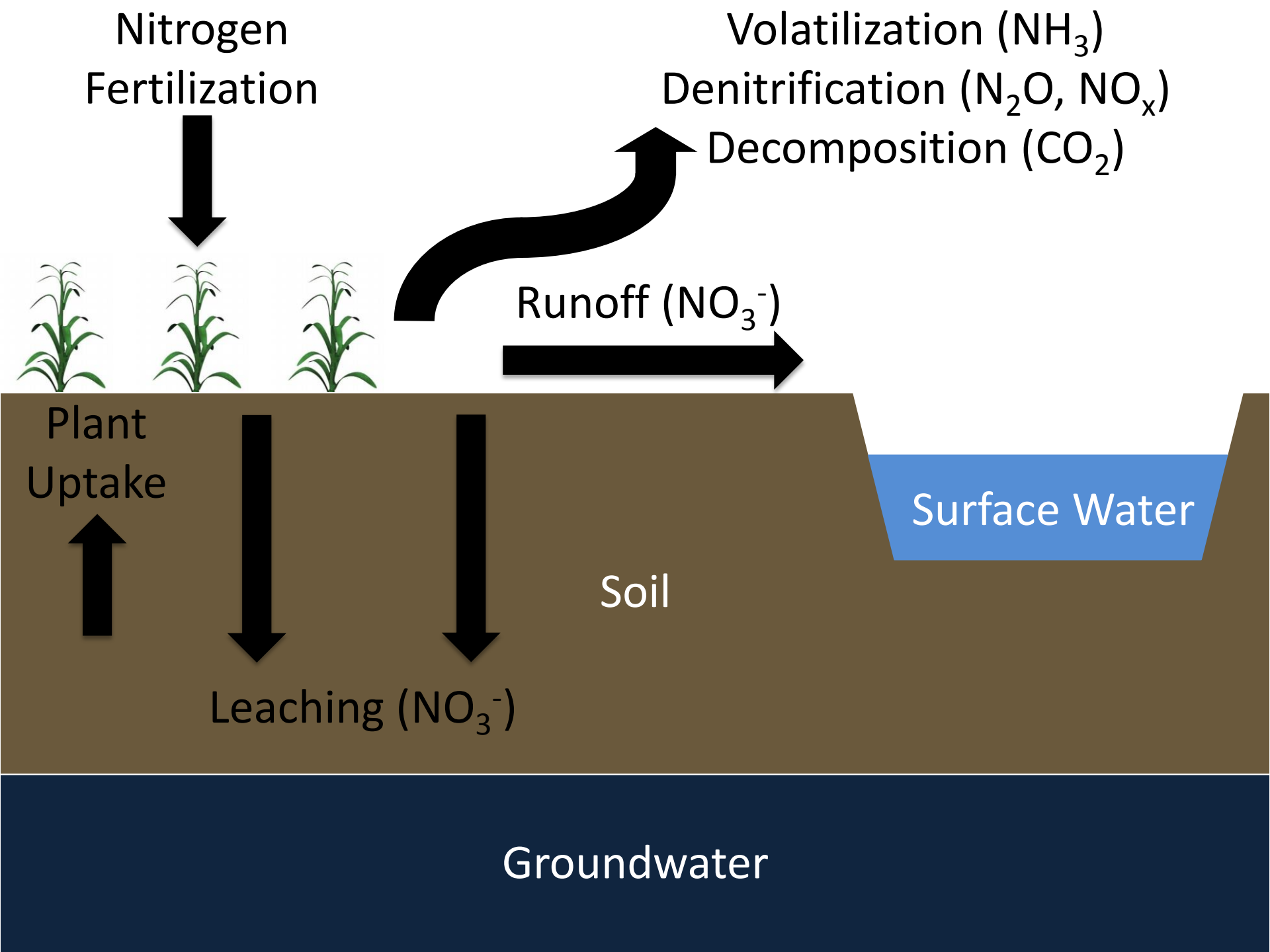
Spatially-explicit damage cost estimates

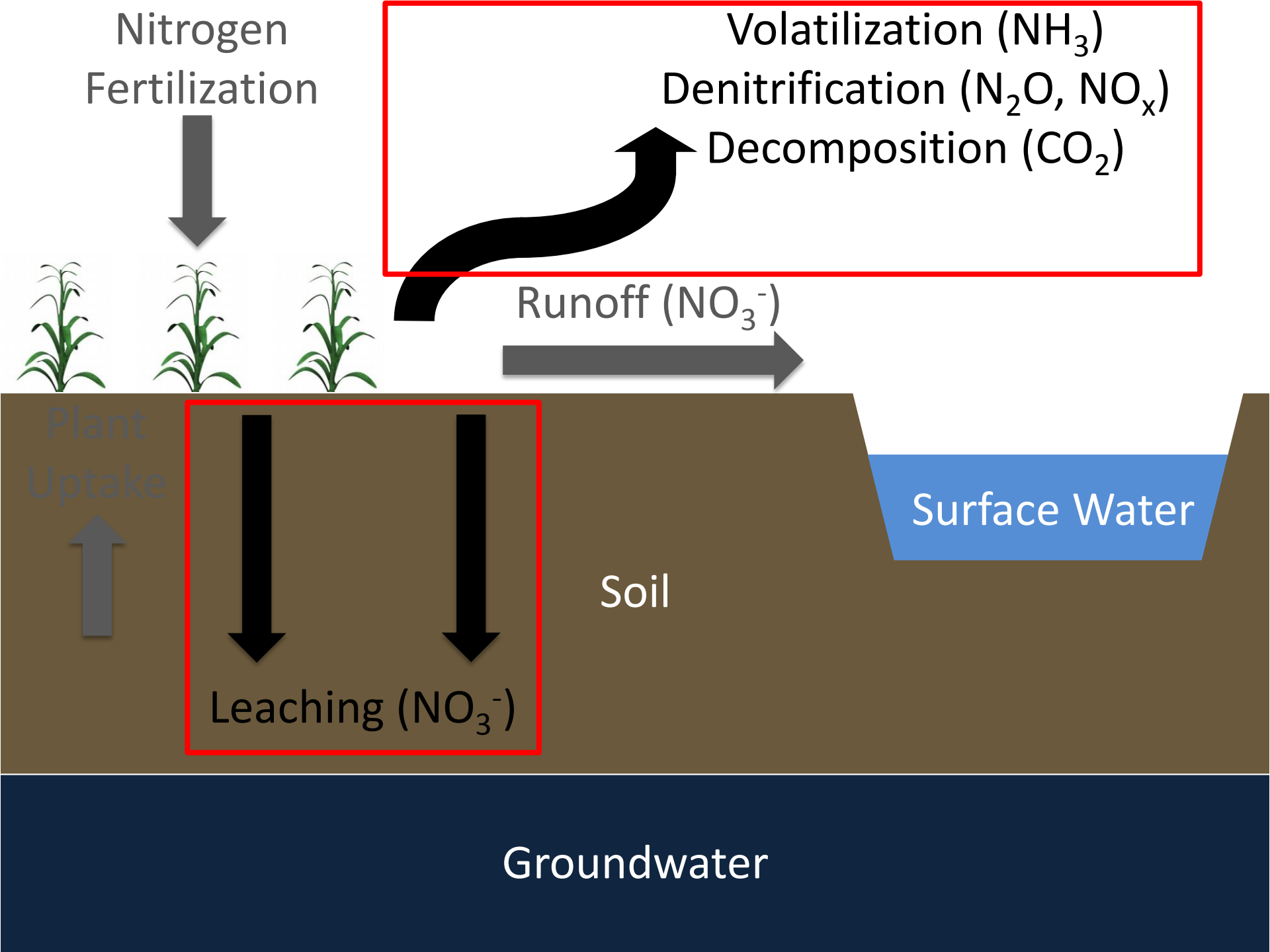
Where do we go from here?

Private benefits of nitrogen fertilizer

External costs to public




Nitrogen Fertilization
Volatilization (NH_3)
Denitrification (N_2O, NO_x)
Decomposition (CO_2)
Runoff (NO_3^-)
Plant Uptake
Surface Water
Soil
Leaching (NO_3^-)
Groundwater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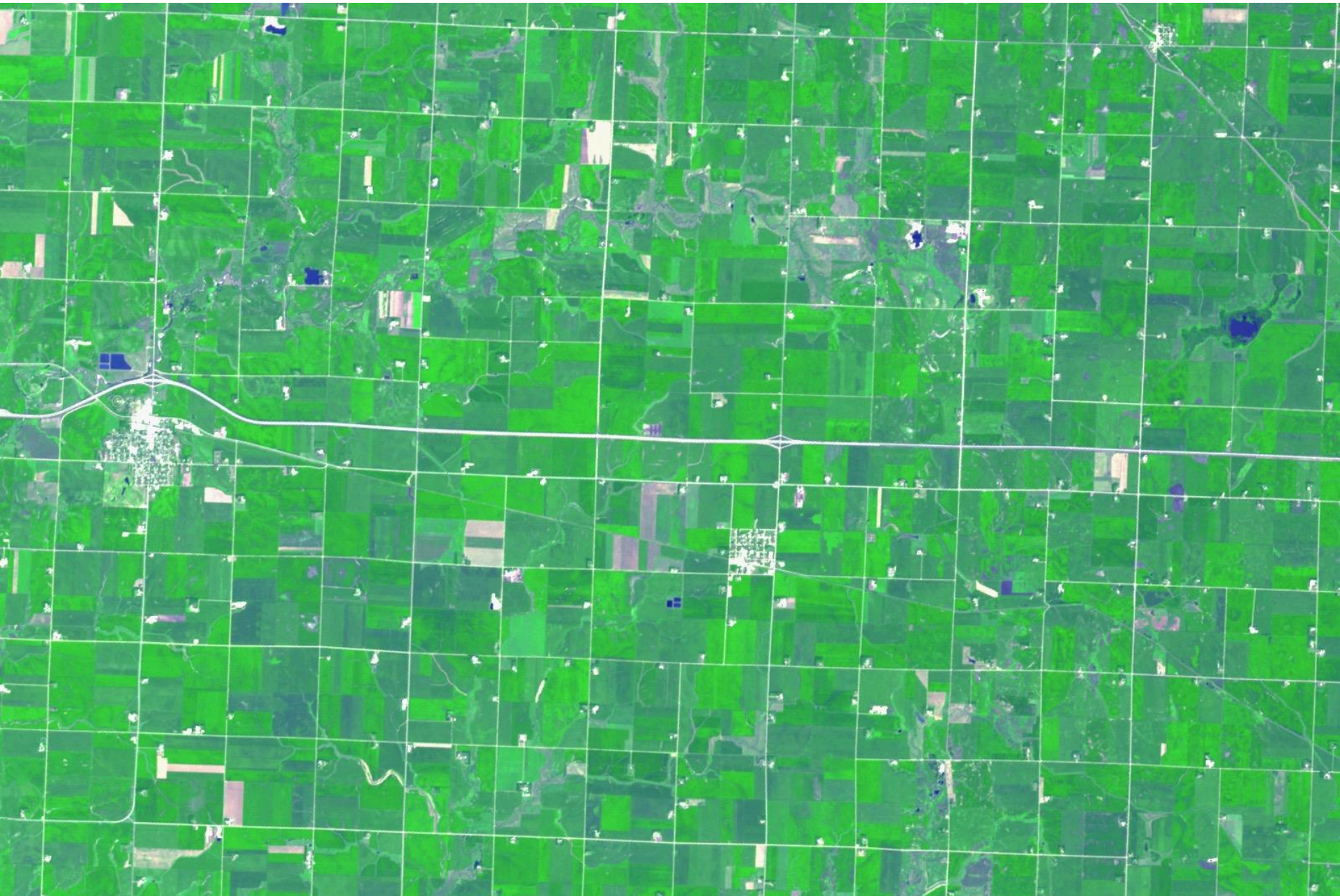
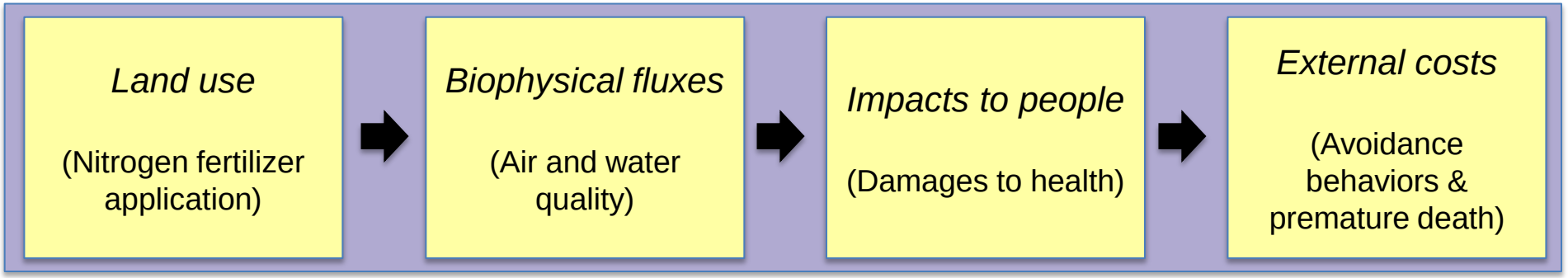
Need for cost estimates

Targeting spatial planning



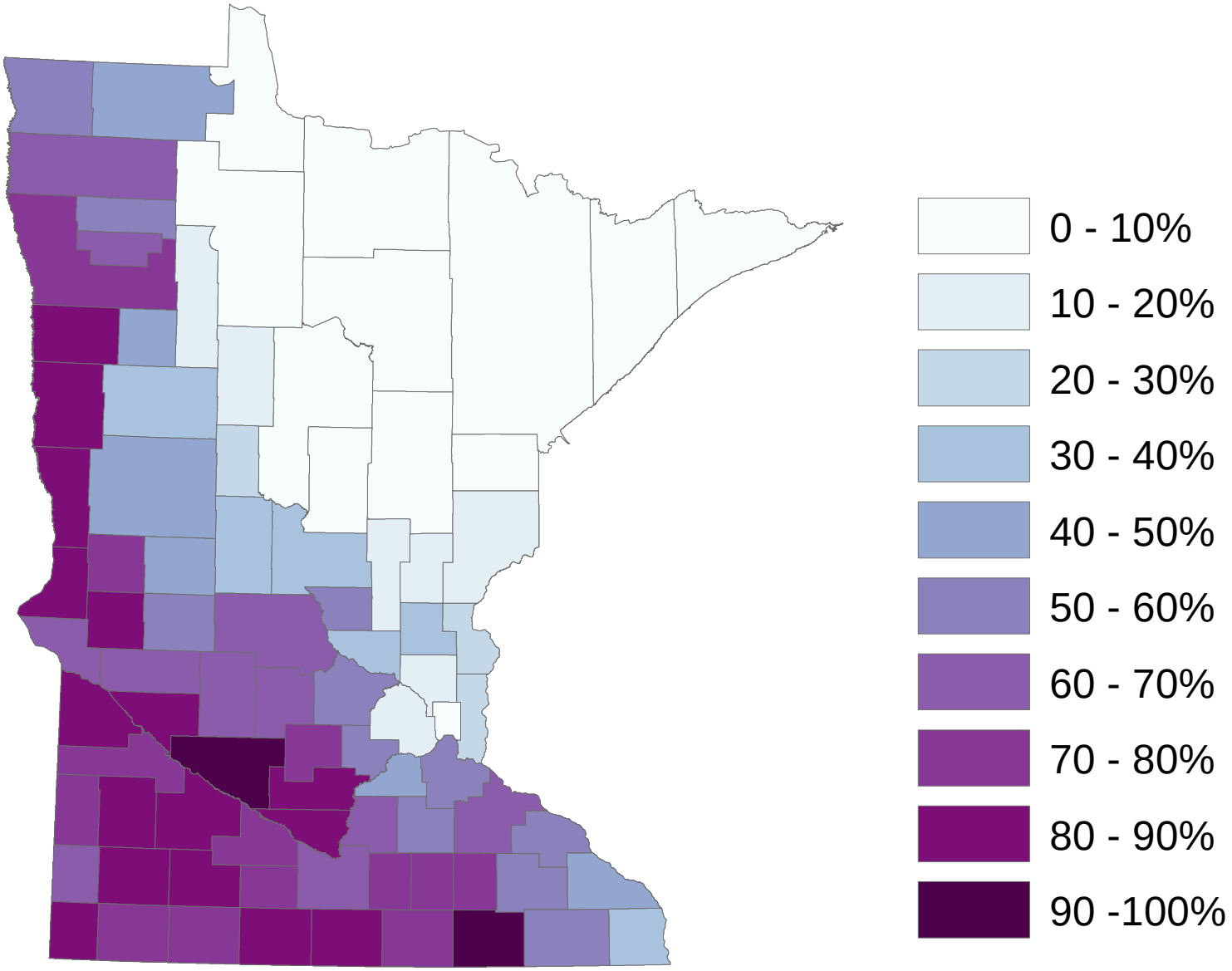
Conceptual framework



Recent land use change across the Midwest

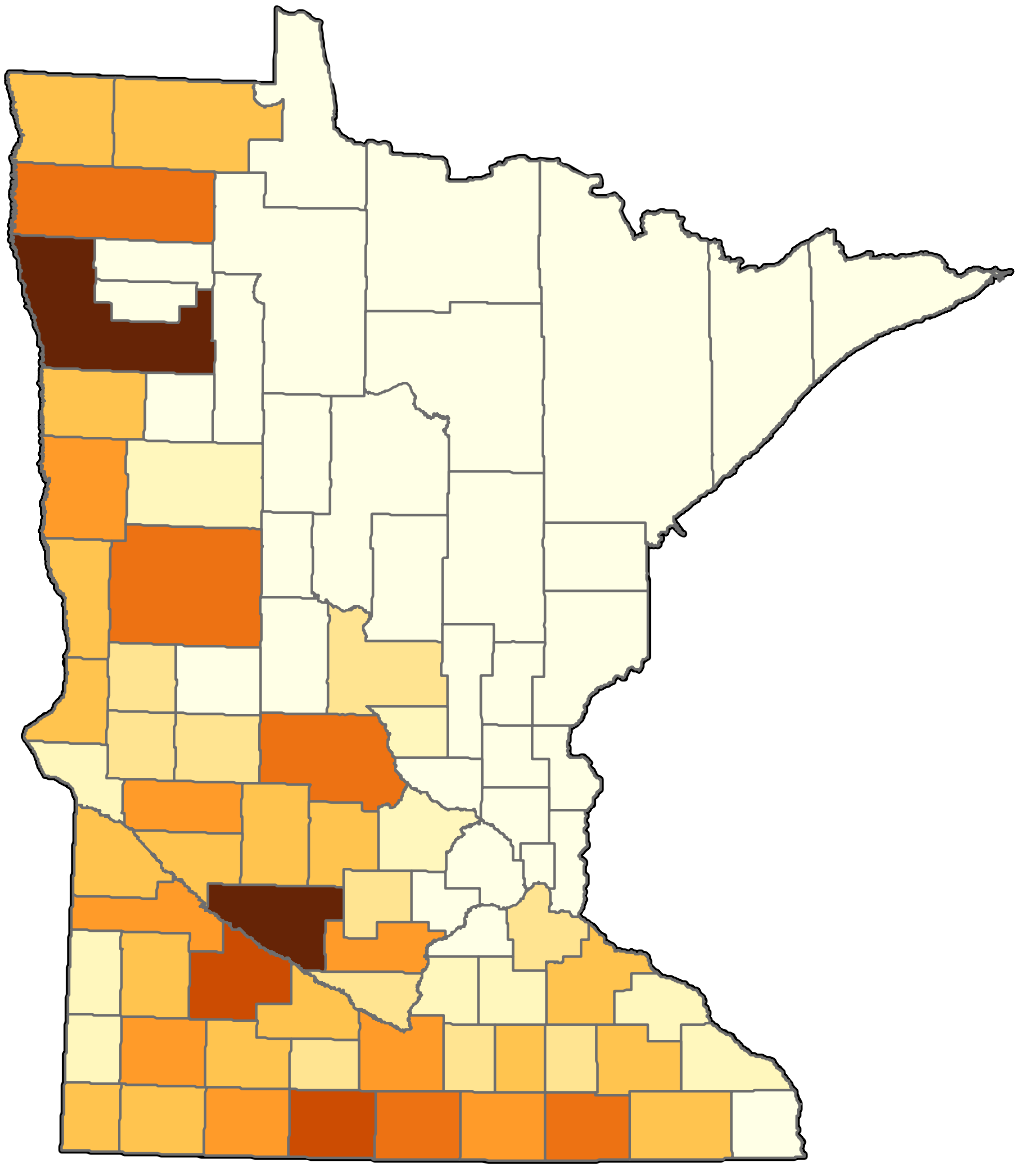
Source: NASS, Noe et al. 2014

~40% of Minnesota land cover is cropland



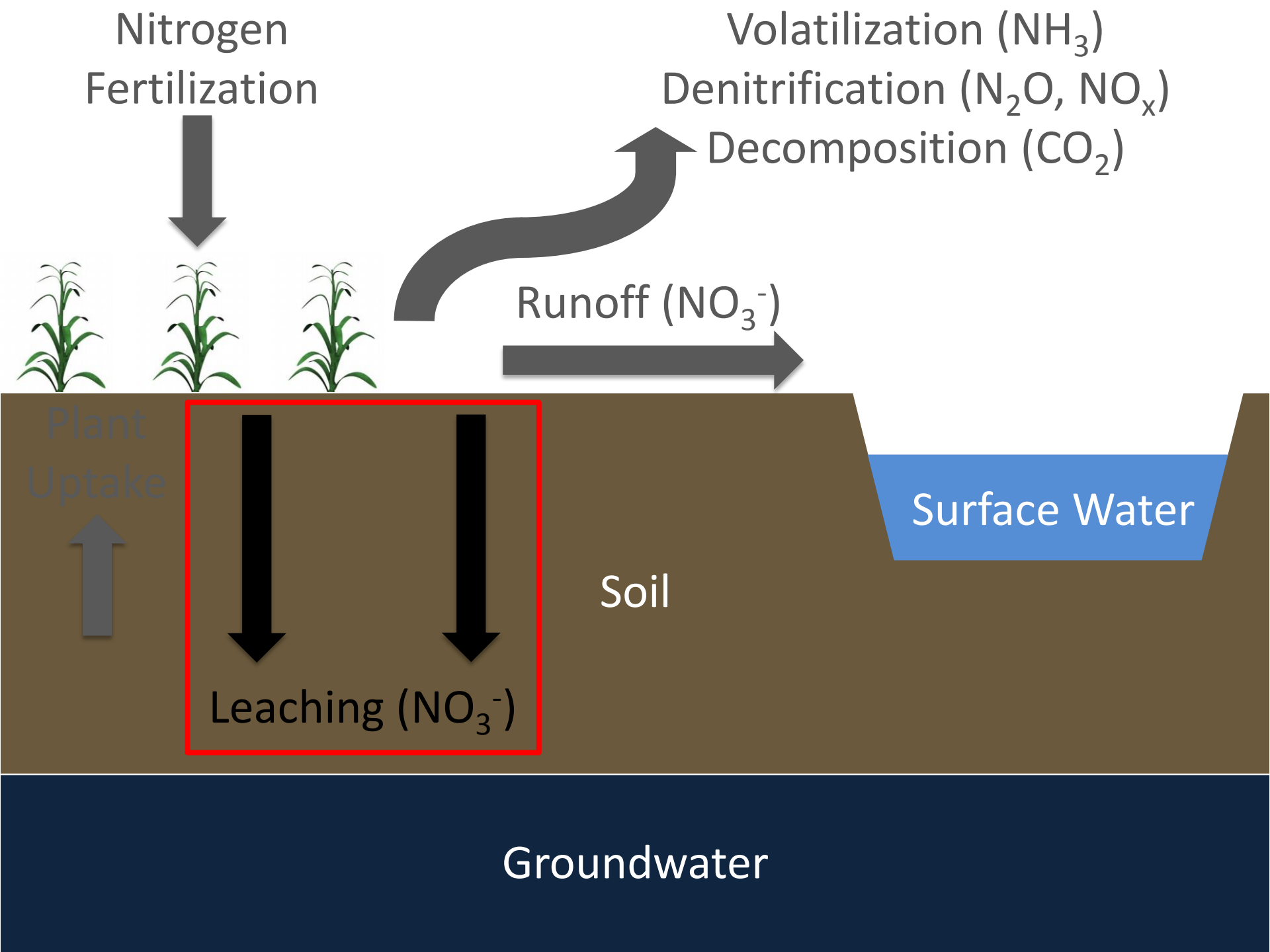
Source: NASS 2012

Over 550 million kg nitrogen fertilizer applied annually



< 2 million
2 - 4 million
4 - 6 million
6 - 8 million
8 - 10 million
10 - 12 million
12 - 14 million
14 - 16 million
16 - 18 million
18 - 20 million
> 20 million

Source: Gronberg and Spahr 2012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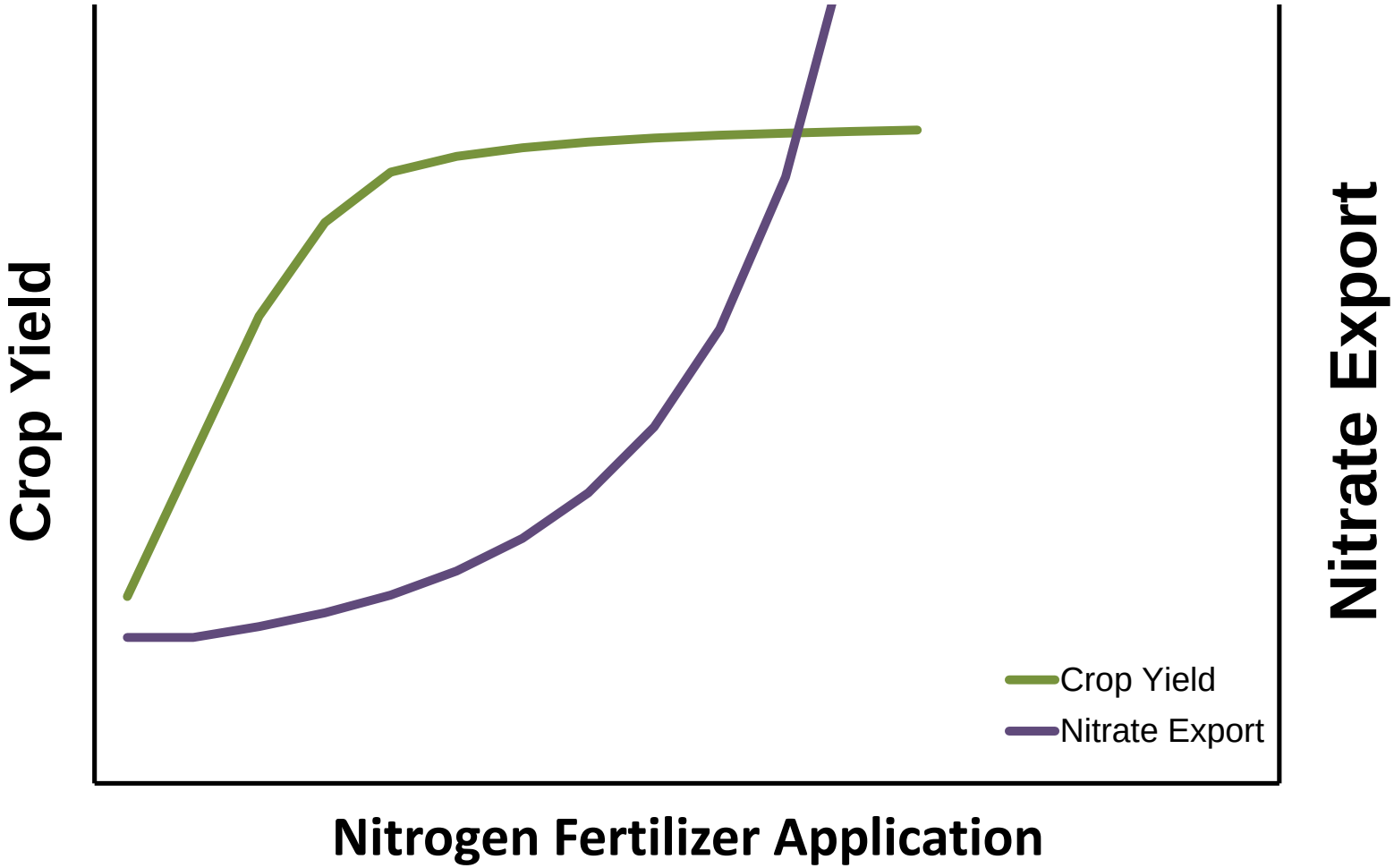
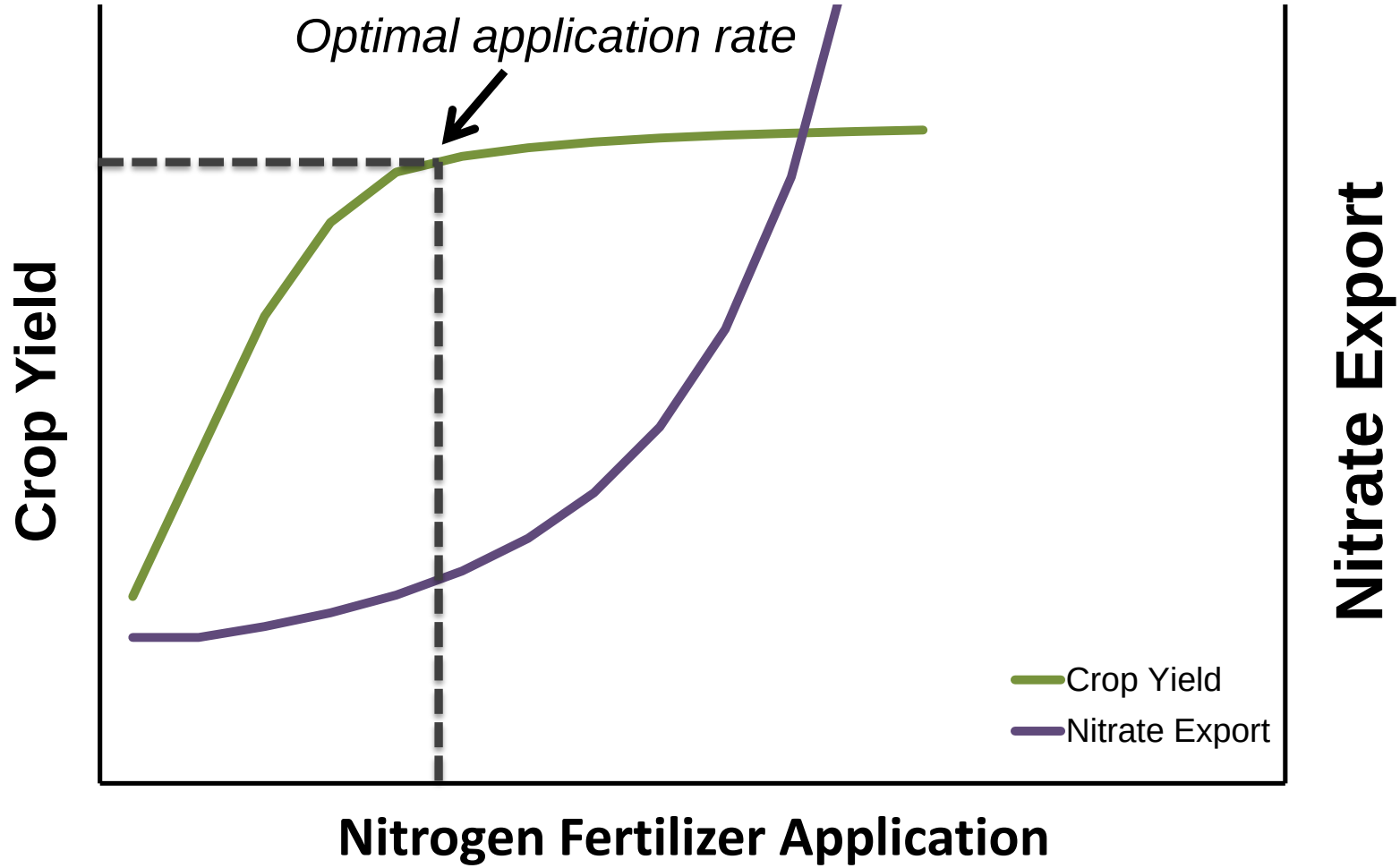
Nitrate loss increases exponentially with application rate



Source: University of Minnesota Extension; Randall et al. 2013

Nitrate loss increases exponentially with application rate



Source: University of Minnesota Extension; Randall et al. 2013

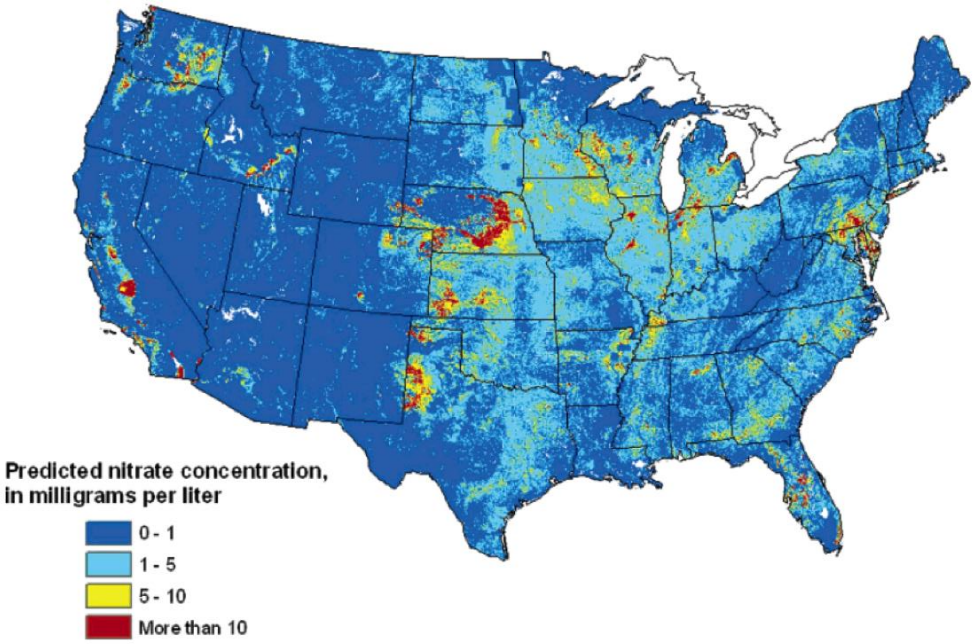
Estimating cost of domestic well contamination

Assemble well datasets and explanatory variables, including nitrate load → *Parameterize logistic regression model using wells with known nitrate* → *Use parameterized model to predict contamination of wells with unknown nitrate* → *Apply surveyed cost estimates to contaminated wells*

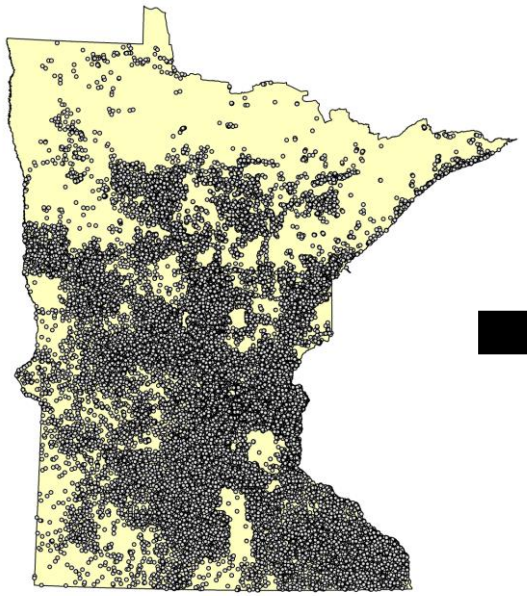
Vulnerability of Shallow Groundwater and Drinking-Water Wells to Nitrate in the United States

BERNARD T. NOLAN* AND KERIE J. HITT

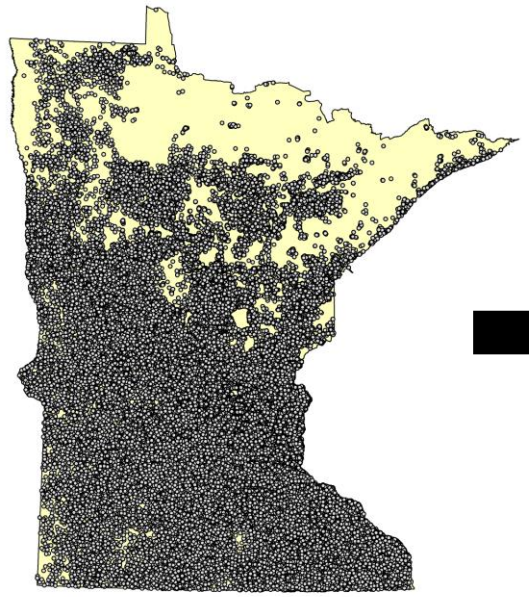
U.S. Geological Survey, 413 National Center, Reston, Virginia 20192



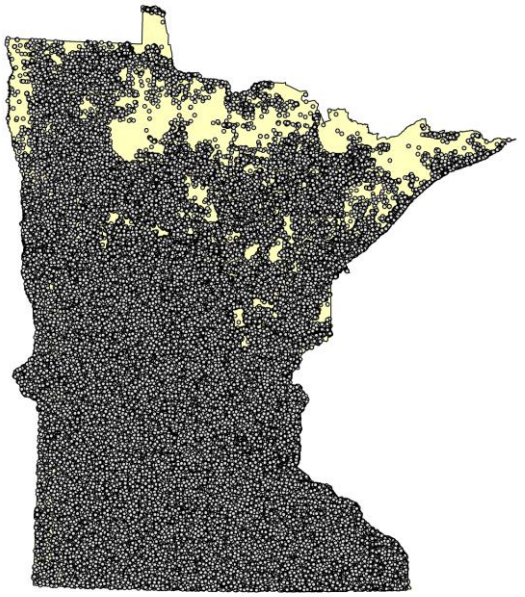
Well datasets



Wells with known nitrate and known location (70,805 wells)



Wells with unknown N and known location (187,034 wells)



Wells with unknown N and approximate location (339,238 wells)

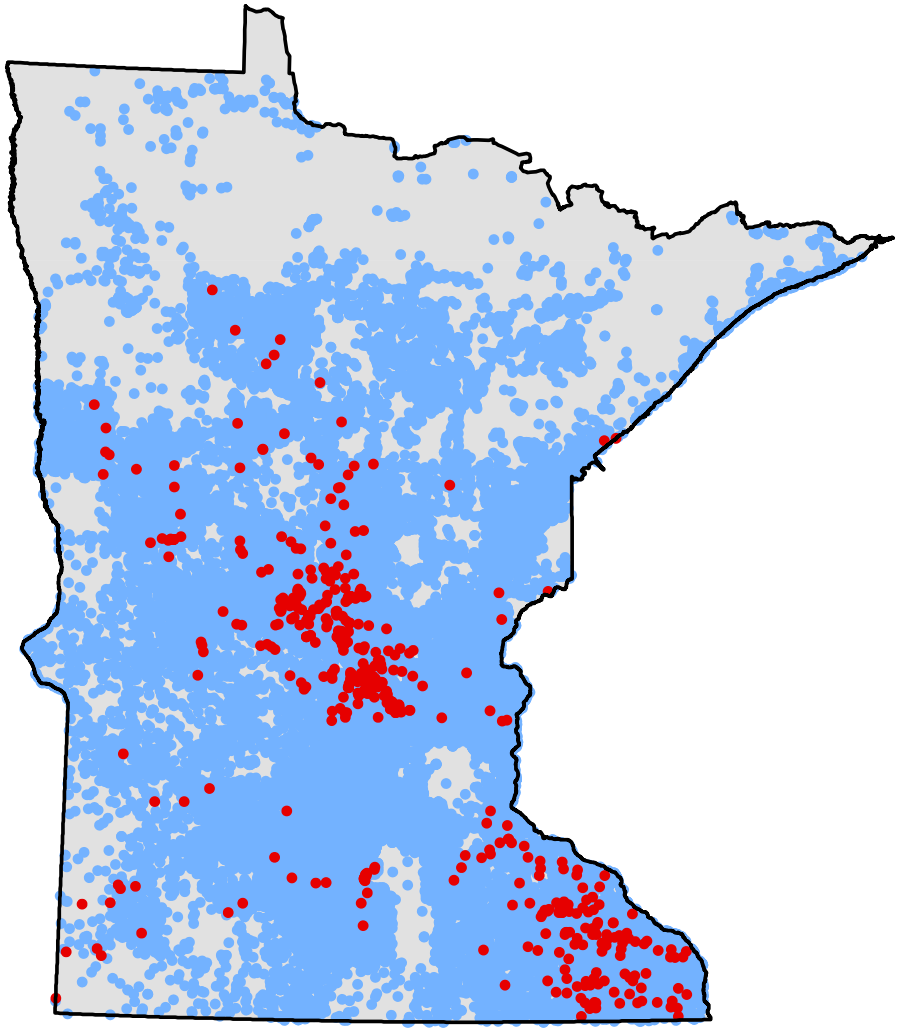
Source: County Well Index

Observed nitrate groundwater contamination

Approximates 70,000 wells with known locations and known nitrate concentrations

Over 500 wells exceed MCL (10 ppm)

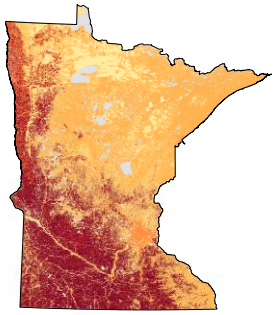
Contamination is concentrated in Central Sands and Southeast, MN



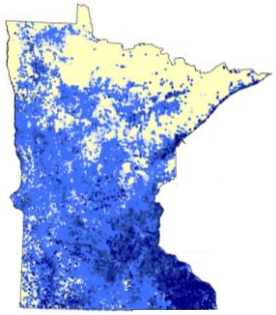
Source: County Well Index

Predicting well contamination using logistic regression

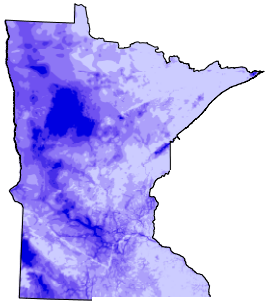
Nitrate Load



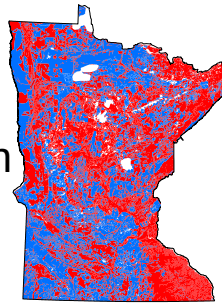
Well Depth

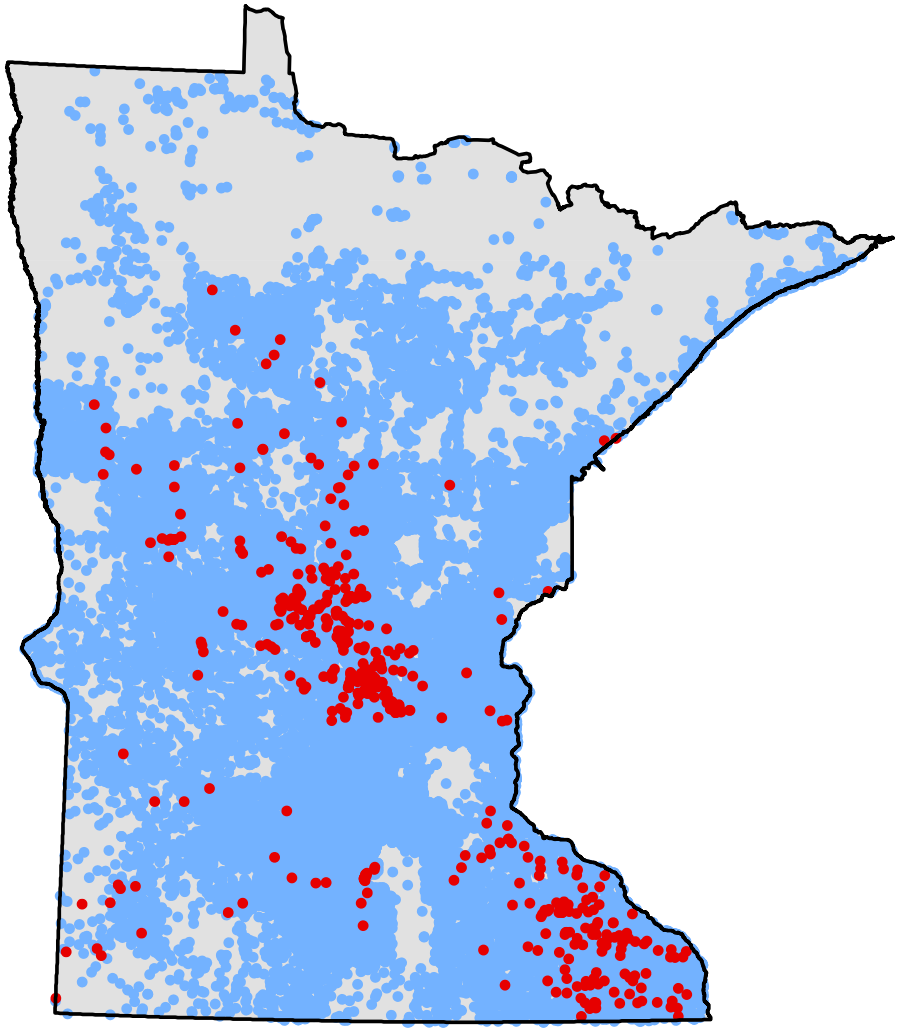


Depth to Bedrock



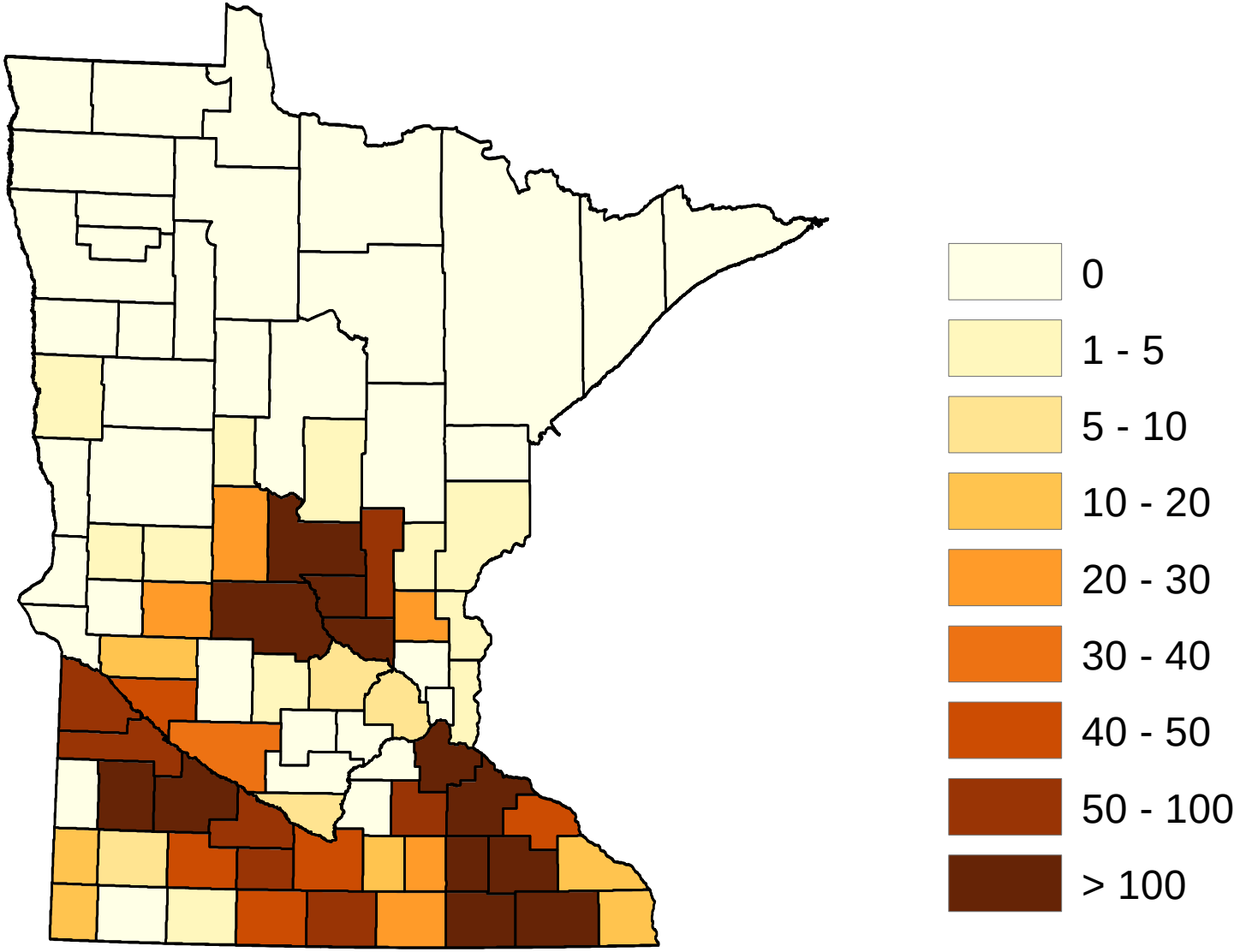
Groundwater Contamination Susceptibility





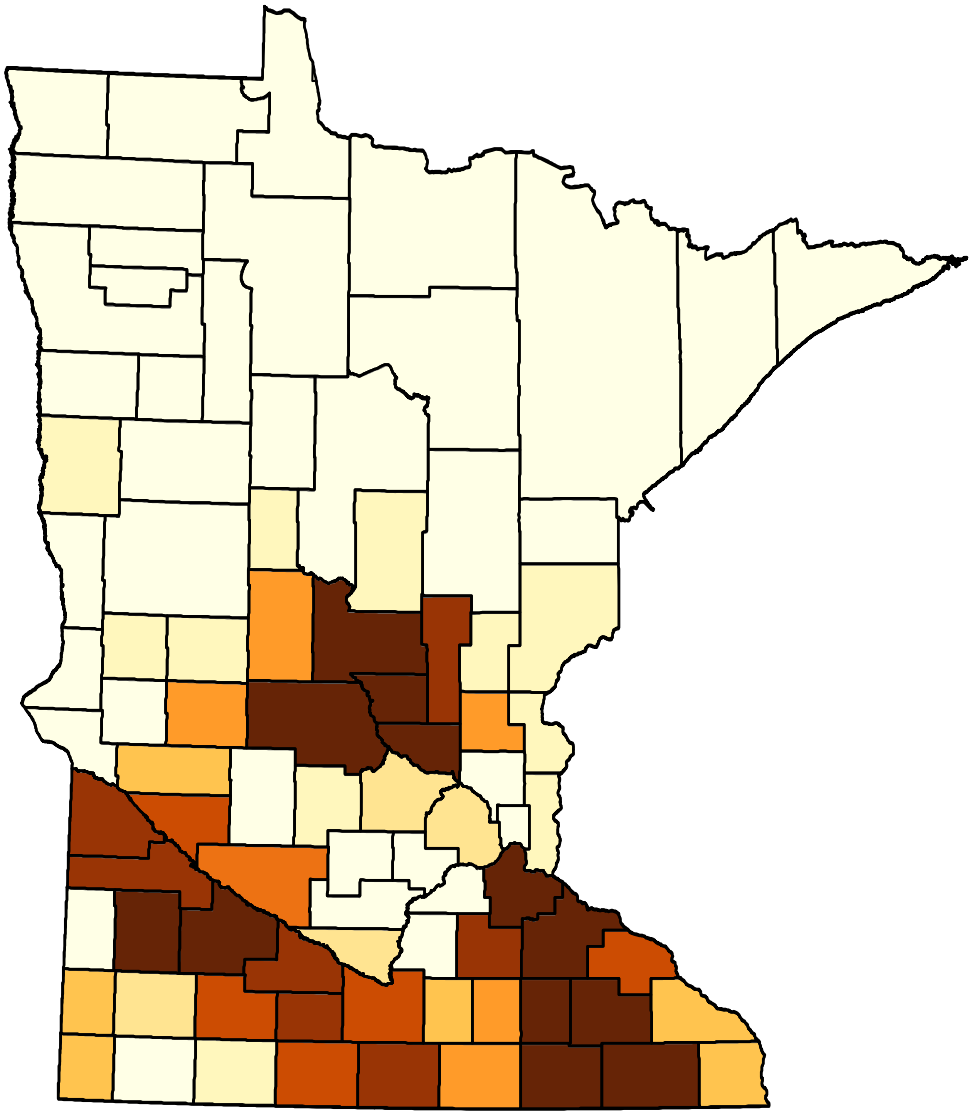
Predicted domestic well contamination

Total number wells contaminated = 4,749



Predicted cost of domestic well contamination

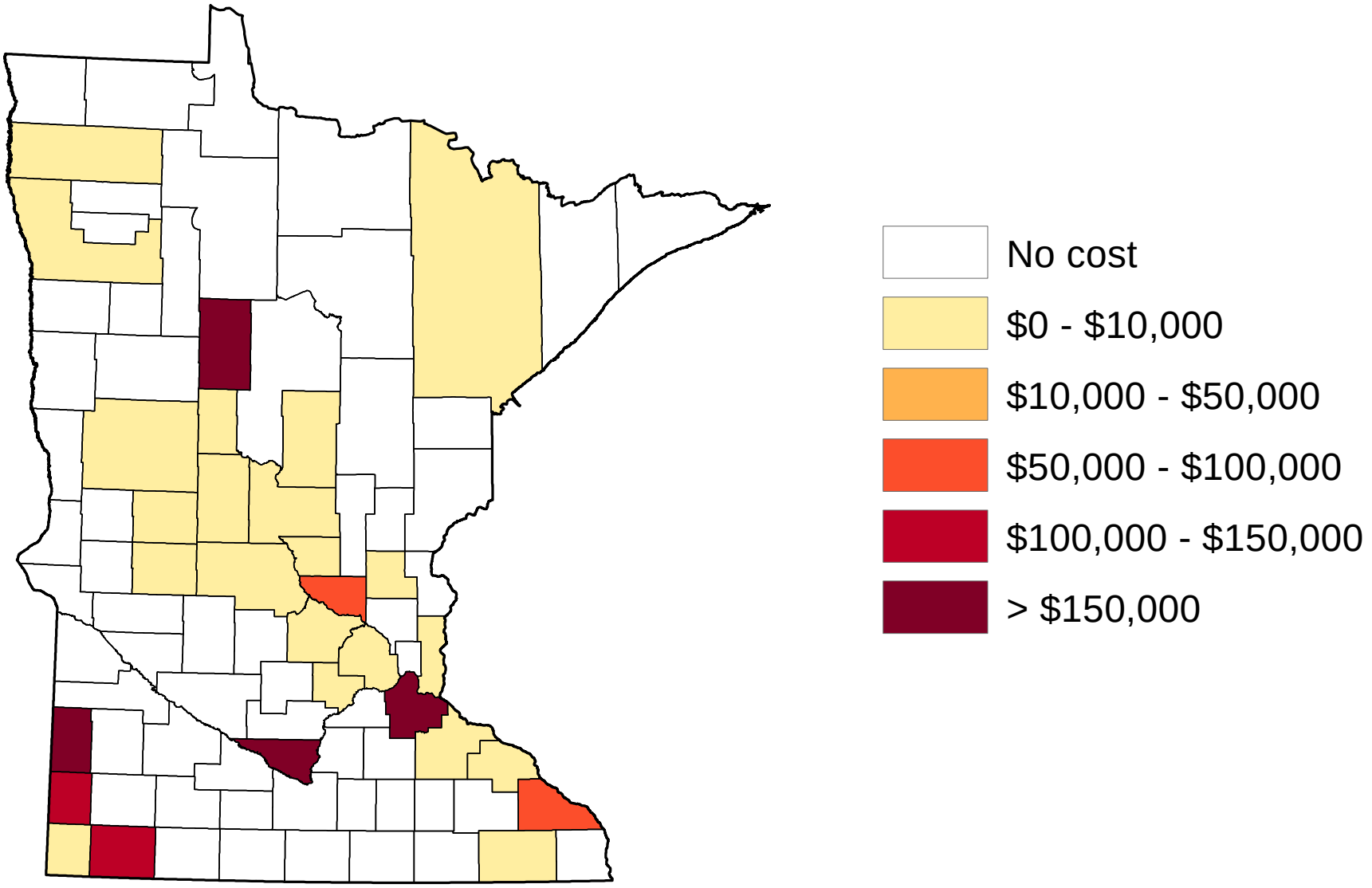
Total annual cost of well contamination = $2.7 million

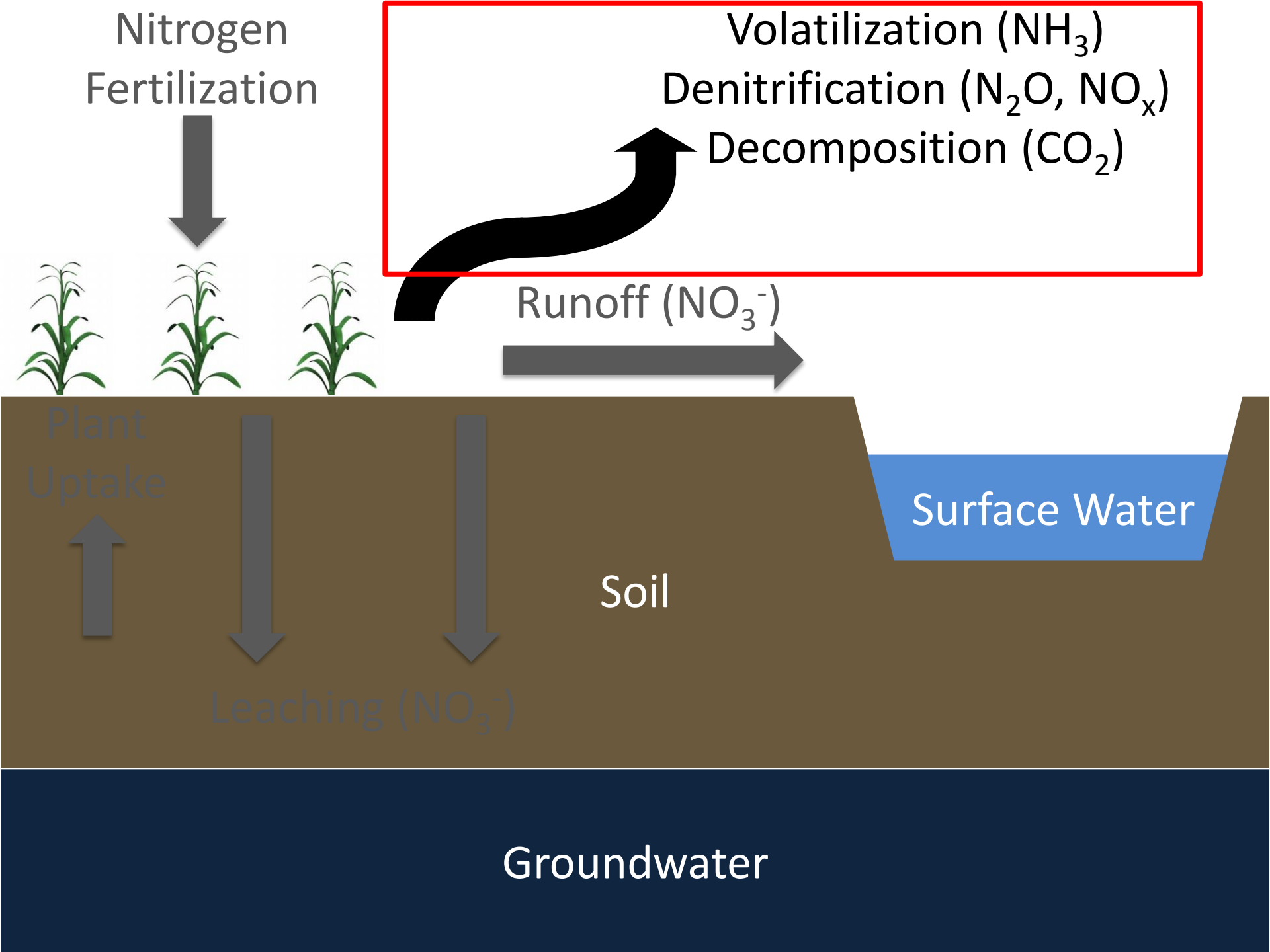


No cost
$500 - $2,500
$2,500 - $5,000
$5,000 - $10,000
$10,000 - $15,000
$15,000 - $20,000
$20,000 - $25,000
$25,000 - $50,000
> $50,000

Costs of public water supply contamination

Annual cost = $4 million

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Damages from air emissions

GHG emissions to damage costs

Social cost of carbon

($0.03/kg CO_2)
($12.95/kg N_2O)

→

Social cost of GHG emissions from fertilizer application

Fertilizer application to emissions

Nitrogen fertilizer application by county

→

Emission factors

GHGs: CO_2, N_2O
Pollutants: NH_3, NO_x

Premature deaths from $PM_{2.5}$

Emissions-to-health impact model

(InMAP)

→

Cost of premature deaths due to PM formation

Cost of GHG emissions

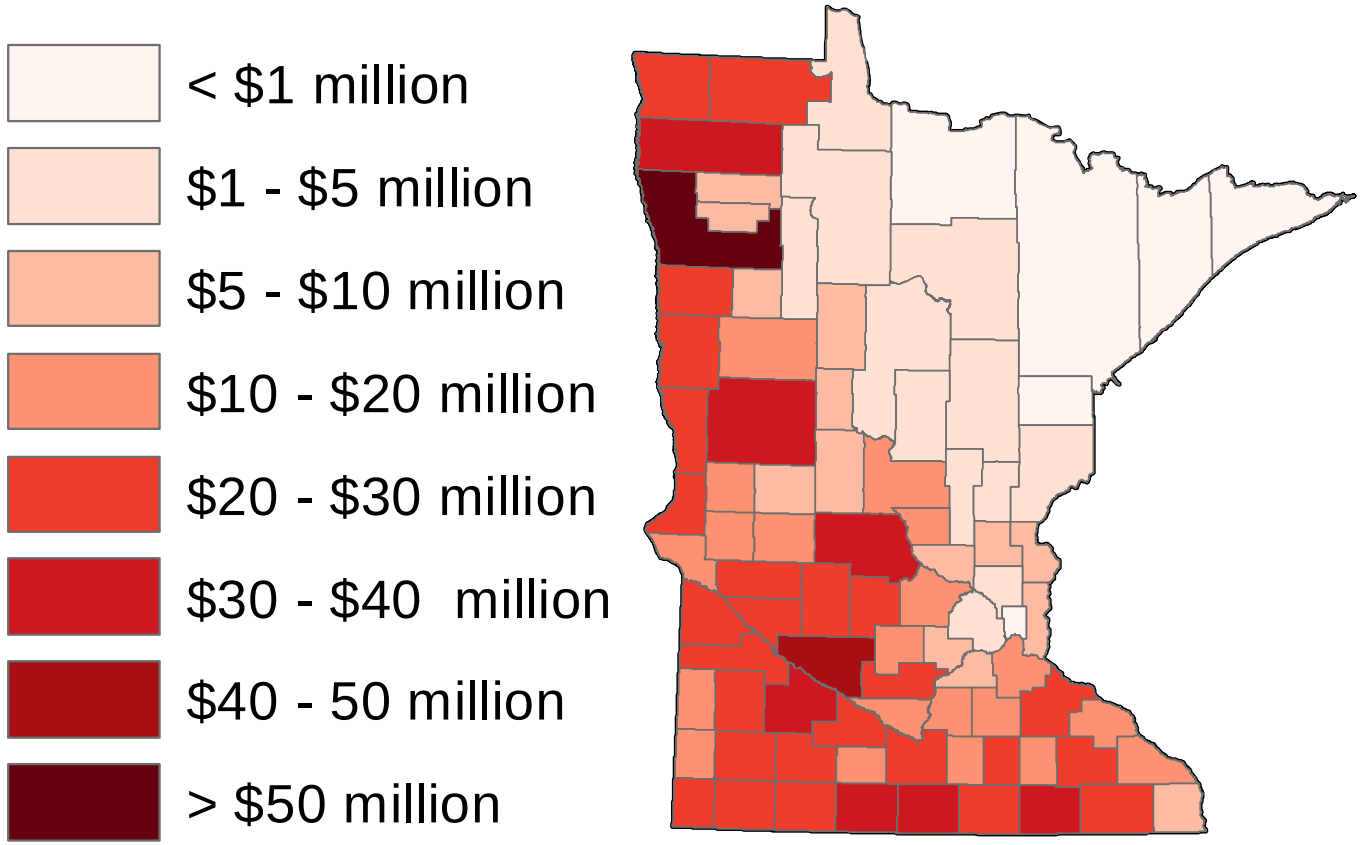
Social cost of carbon

($0.03/kg CO_2)
($12.95/kg N_2O)

→

Social cost of GHG emissions from fertilizer application

Annual cost = $96 million



Cost of premature deaths from $PM_{2.5}$

Emissions-to-health impact model

(InMAP)

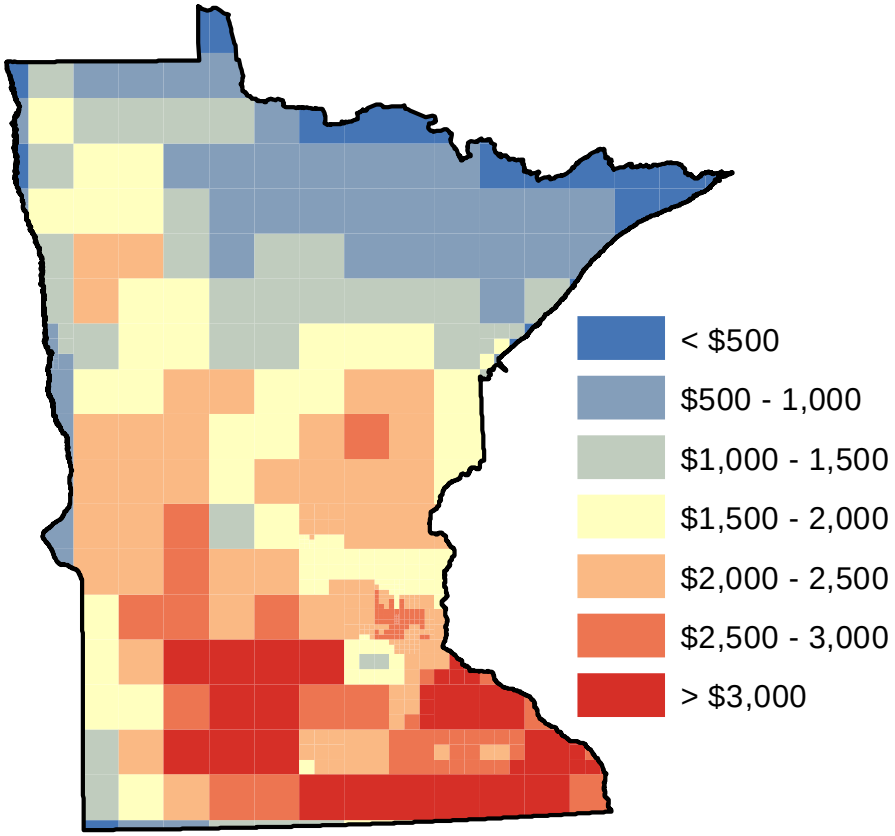
→

Cost of premature deaths due to PM formation

Annual premature deaths = 86

Annual Cost = $791 million

Per capita cost to each parcel



Cost of premature deaths from $PM_{2.5}$

Emissions-to-health impact model

(InMAP)

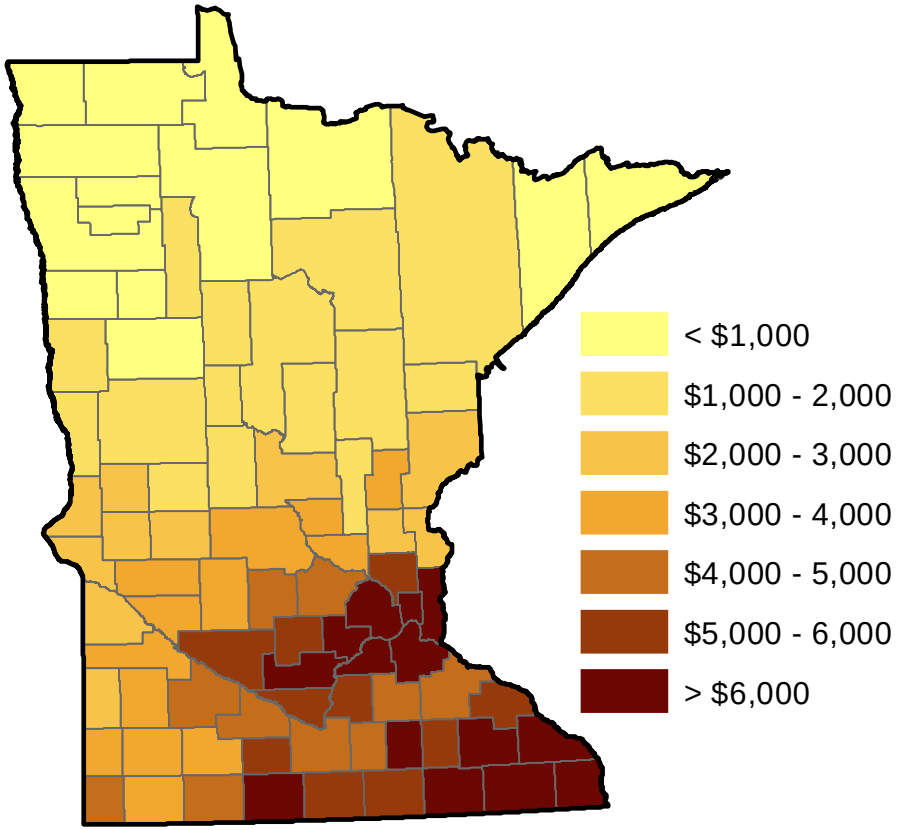
→

Cost of premature deaths due to PM formation

Annual premature deaths = 86

Annual Cost = $791 million

Per hectare cropland cost from each county



Summary of annual costs

Damage	Cost estimate
Domestic well contamination	$3 million
Public water supplier contamination	$4 million
Greenhouse gas emissions	$96 million
Air pollutant emissions	$791 million
TOTAL	**$893 million**

Land-Use Scenarios

Fertilizer management scenario:

Reducing fertilizer application by 20% is estimated to reduce external costs of nitrogen fertilizer application by 22% ($200 million annually)

Business-as-usual scenario:

Fertilizer application in 2012, as compared with in 2007, is estimated to increase costs by 10% ($86 million annually)

Other costs associated with nitrogen

Nitrate and human health

Nitrate and aquatic pests and parasites

Nitrate and livestock

Nitrate and property values

Nitrate and aquatic ecosystems

Take-away messages

There are large benefits of fertilizer application. However, there are also many external costs

These costs are incurred by society and are clustered in particular regions of the Minnesota

By estimating the social costs of nitrogen, we can:

1. **Better quantify the benefits of fertilizer regulations**
2. **Spatially target interventions for improved fertilizer management**

Acknowledgements

My co-author: Bonnie Keeler

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Questions?